GALACTIC ULTRA-COMPACT BINARIES IN GRAVITATIONAL WAVES

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Storyline

The GW Galaxy in UCBs

So many binaries!

Astrophysical motivations



The Milky Way

- Diameter: 100,000 lightyears
- Mass: 7.0 x 10¹¹ M⊙
- Number of stars: ~200 billion
- 10-80 million compact binaries
 - P_{orb} < few hours
 - Compact stellar remnants
- PERSISTENT GW SOURCES



A PROBE OF THE FOSSIL RECORD OF THE GALAXY

In the Fossil Record

- In the fossil record there is information that is (at best) hard to get any other way except with gravitational waves
- The shape of the galaxy directly to the far edge (beyond the Zone)
- An encoded record of the joint evolutionary history of stellar binaries
- Tides modify the GW inspiral, probing compact remnant structure
- Tests of General Relativity (particularly with multimessenger systems)
 - and so on...

Confusion Foreground



- There are so many binaries, it is difficult to tell them apart below ~3mHz
- Irreducible form of astrophysical signal ("noise")
- This is the "confusion limit", analogous to a cocktail party
 - You can hear people nearby and loud people
 - All else is a **dull noise**



Hils, Bender, Webbink (1990) Hils, Bender (1997) Timpano, Rubbo, Cornish (2006)

Nelemans, Yungelson, Portegeis-Zwart (2001) Ruiter, Belczynski, Benacquista, SLL (2010)

The Low Frequency Galaxy



Verification & Resolvable Binaries



 The ultra-compact binaries are guaranteed sources for any low-frequency observatory.

The Resolvable Galaxy



 Resolvable binaries can be separated from the background, and retain information about the distribution of systems on the sky

Chirping Binaries

 Of the 10,000 resolvable binaries, a couple of thousand will be chirping

 $h=rac{\mathcal{M}_c}{D}\left(\pi f\mathcal{M}_c
ight)^{2/3}$ $\dot{f} = rac{96}{5} rac{f}{\mathcal{M}_c} \left(\pi f \mathcal{M}_c
ight)^{8/3}$ $D = rac{5}{96 \pi^2} rac{1}{h} rac{\dot{f}}{f^3}$

• 3D information!



The Shape of the Galaxy



3D population maps out the shape of the Milky Way (scale heights)

Adams, Cornish, Littenberg [2012] --- scale heights to a few %

SN la Progenitors

Stroeer, Benacquista & Ceballos [2013]

- GW give you measures of the masses of the systems
- Measure the mass and period distribution of SN Ia progenitors



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Multi-Messenger Binaries



There are known sources because we can SEE them in telescopes!

How many multi-messenger binaries?





Binary can be seen across the galaxy in gravitational waves

EM obs are limited by intrinsic brightness, and extinction

CV Accretion Disks

Addison, Breivik, SLL [2014]



Low mass secondaries can expand to fill their Roche lobe and overflow
Overflow stream can cross, and if it does will form an accretion disk

CV Accretion Disks



Light curve shows lot of structure, but dominated by two components:

- Ellipsoidal variations (rotating Roche lobe)
- Hot spot from impact on accretion disk

CV Accretion Disks

Addison, Breivik, SLL [2014]



- Gravitational wave phase gives geometric information to fit out the ellipsoidal variations
- Phase of the hot spot given by the residual lightcurve

Last Thoughts

These are real sources, they can be seen.

- Right now, you and I are bathing in gravitational waves from the binaries!
- The astrophysics associated with the binaries is rich and largely unexplored
- Conversations with stellar astronomers will reveal questions they have.
- GW is a tool that can help with masses, with geometry, with population statistics, and more

